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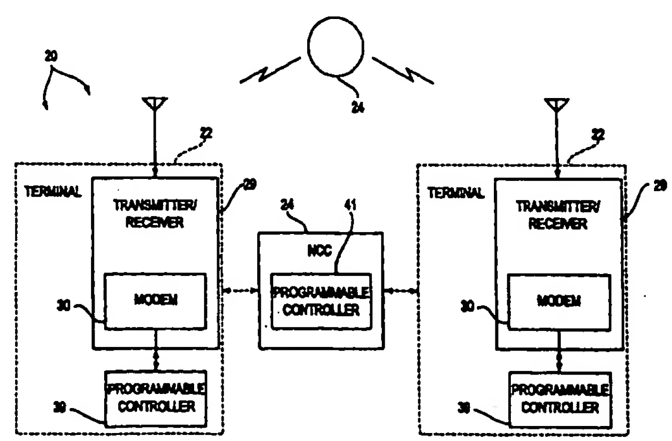

(57) Abstract

A method is presented which compensates for changes in the quality of an RF link by adaptively varying the type of modulation utilized over the RF link in response to changes in link conditions, whereby the gain and information throughput over that RF link are adaptively varied in dependence upon link conditions, while maintaining a constant symbol rate. In a presently contemplated embodiment, this method is implemented in a satellite communications network that includes two or more terminals (22) and a network controller (NCC) (24) by monitoring various modem performance parameters at the terminals (22). The NCC (24) then transmits control data to the terminals (22) to adaptively vary the type of modulation used in allocating bursts between various pairs of terminals (22) in dependence upon the monitored link conditions. In a specifically contemplated embodiment, the modulation type is changed from QPSK to BPSK in response to link degradation (e.g., due to heavy rain), thereby providing 3 dB of gain. The change from QPSK to BPSK modulation necessitates that the information throughput be reduced by a factor of 2, thereby maintaining a constant symbol rate.

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ADAPTIVE MODULATION TECHNIQUE
AND
SATELLITE COMMUNICATION NETWORK
IMPLEMENTING THE SAME

BACKGROUND OF THE INVENTION

The present invention relates generally to techniques for compensating for link degradation in an RF communications system, and more particularly, to a technique and system for adaptively varying the type of modulation employed in a satellite communications network, e.g., between Quarternary Phase Shift Keying (QPSK) and Binary Phase Shift Keying (BPSK), in dependence upon monitored link quality or conditions, e.g., environmental conditions such as clear sky or heavy rain.

This application is based on and claims priority from provisional patent applications, Serial Nos. 60/064,673, 60/062,497 and 60/062,496, which are incorporated herein by reference for all purposes.

In general, satellite communications systems operating at high frequencies, such as at Ku and Ka frequency bands, are susceptible to signal attenuation of several dBs in a rain fade environment. In many satellite communications systems, it is not economically feasible to design the satellite links to compensate for rain fade. On the other hand, satellite links designed for clear sky conditions will fail to operate properly in a rain fade environment. In general, when environmental conditions for a given link are favorable (e.g., clear sky), high throughput may be achieved via that link, whereas the throughput that can be achieved is reduced as the link degrades (e.g., in the presence of rain fade). Thus, achievable throughput is dependent upon link quality or conditions, e.g., environmental conditions such as clear sky or heavy rain.

In light of the above, what is needed is a satellite communications network that is adaptive to the prevailing environmental conditions for a given satellite link at the time of transmission. Several schemes have previously been proposed for adjusting the throughput via a given link as the link degrades. One such scheme utilizes an adaptive rate forward error correction (FEC) code, according to which the code rate is decreased in order to provide greater error protection in the presence of adverse link conditions, thereby decreasing the information throughput, and is increased in order to provide less error protection in the presence of favorable link conditions, thereby increasing the information throughput. It should be appreciated that if the code rate is decreased, the information throughput must be reduced commensurately in order to ensure a constant data (symbol) rate. Another such scheme actually reduces the data (symbol) rate in response to link degradation, which requires a modem having the capability to transmit at multiple data rates. A significant disadvantage of both of these schemes is that they increase the size, complexity, and cost of the terminal transmit/receive equipment.

Based on the above and foregoing, it can be appreciated that there presently exists a need in the art for a technique for varying information throughput over an RF link in dependence upon link quality or conditions which overcomes the disadvantages and shortcomings of the presently available technology discussed above. Such a scheme which responds to changes in link conditions as rapidly as possible is most desirable.

SUMMARY OF THE INVENTION

The present invention encompasses a method which compensates for changes in the quality of an RF link by adaptively varying the type of modulation utilized over the RF link in response to changes in link conditions, whereby the gain and information throughput over that RF link are adaptively varied in dependence upon link conditions, while maintaining a constant symbol rate. In a presently contemplated exemplary embodiment, this method is implemented in a satellite communications network that includes two or more terminals and a network control center (NCC) by monitoring various modem performance parameters at the terminals and periodically reporting the resultant modem performance data to the NCC. The NCC then transmits control data to the terminals to adaptively vary the type of modulation used in allocating bursts between various pairs of terminals, in dependence upon the monitored link conditions. In a specifically contemplated embodiment, the modulation type is changed from

QPSK to BPSK in response to link degradation (e.g., due to heavy rain), thereby providing 3 dB of gain. The change from QPSK to BPSK modulation necessitates that the information throughput be reduced by a factor of 2, thereby maintaining a constant symbol rate.

In the specifically contemplated embodiment, the satellite communication network of the present invention includes a plurality of terminals each of which is equipped with an RF transmitter/receiver that includes a modem and a programmable controller, and which produces modem performance information indicative of modem performance, and a network control center that includes a programmable network controller. The programmable controller of each terminal is programmed to periodically monitor the modem performance information and to produce link condition information that includes a current value of at least parameter of modem performance. The programmable network controller is programmed to periodically determine a preferred modulation type for each pair of the terminals that define a link, based upon the link condition information received from the terminals, and to periodically send modulation type control information indicative of the preferred modulation type to a modulation type control portion of both a sender and a receiver terminal of a link currently being controlled. The modulation type control portion of both the sender and receiver terminals adaptively varies a modulation type used by the modem in the terminal, in response to the modulation type control information.

Preferably, the satellite communication network employs a communication protocol in which the smallest unit of bandwidth allocation is a burst, and the programmable network controller includes a capacity manager functional entity that allocates bursts and generates the modulation type control information on a burst-by-burst basis when allocating bursts. The programmable controller in each terminal includes a performance reporter functional entity in the receiver station that periodically sends the link condition information in the form of modem performance reports.

The programmable network controller includes a database that includes a modulation translation table that contains data entries indicating a preferred modulation type for different possible link conditions, and a terminal status table that contains data entries indicating the preferred modulation type for each terminal in the network for the current link conditions. The programmable network controller also includes a performance manager functional entity that

updates the terminal status table in response to the modem performance reports, using the modulation translation table. The capacity manager functional entity generates the modulation type control information based upon the data entries in the terminal status table for the sender and receiver terminals of the link currently being controlled.

BRIEF DESCRIPTION OF THE DRAWINGS

These and various other features and aspects of the present invention will be readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram that depicts a satellite communication system that includes an adaptive modulation subsystem according to the present invention; and,

FIG. 2 is a diagram that depicts the various functional entities and data structures of the adaptive modulation subsystem according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will first be described in general methodological terms, and will then be described in terms of an exemplary implementation of this general methodology in a generic satellite communications system. As will become readily apparent to those having ordinary skill in the pertinent art, the present invention is not limited to any particular application, environment, or implementation, but rather, may have utility in a broad spectrum of different applications, environments, and implementations.

In broad terms, the present invention encompasses the basic methodology of adaptively varying the type of modulation utilized over an RF link in response to changes in link conditions, whereby the gain and information throughput over that RF link are adaptively varied in dependence upon link conditions, while maintaining a constant symbol rate. In a presently contemplated exemplary embodiment, this methodology is implemented in a satellite communications network that includes two or more terminals and a network control center

(NCC) by monitoring various modem performance parameters at the terminals and periodically reporting the resultant modem performance data to the NCC. The NCC then transmits control data to the terminals to adaptively vary the type of modulation used in allocating bursts between various pairs of terminals, in dependence upon the monitored link conditions. In a specifically contemplated embodiment, the modulation type is changed from QPSK to BPSK in response to link degradation (e.g., due to heavy rain), thereby providing 3 dB of gain. The change from QPSK to BPSK modulation necessitates that the information throughput be reduced by a factor of 2, thereby maintaining a constant symbol rate.

With reference now to FIG. 1, there will now be described an exemplary implementation of the present invention within a satellite communication network 20 that includes at least two terminals 22 and a network control center (NCC) 24. In a specifically contemplated implementation, the satellite communication network 20 has a full-mesh topology, whereby each of the terminals 22 can communicate directly with each other via a satellite transponder 24, and can each communicate with the NCC 24 for the purpose of exchanging control information. The communication access scheme used in this specifically contemplated implementation is Frequency Division Multiple Access (FDMA)/Time Division Multiple Access (TDMA), in which multiple carriers are used and intervals of time (time slots) are allocated on those multiple carriers for communication between pairs of terminals. However, it will be appreciated that any other suitable communication access scheme, e.g., Code Division Multiple Access (CDMA) may alternatively be used.

At any given time, a pair of terminals 22 that are in direct communication via the satellite transponder 24 define a link that includes a satellite uplink between the source (sender terminal) and the satellite transponder 24, and a satellite downlink between the satellite transponder and the destination (receiver terminal). One terminal, commonly referred to as the "reference station", transmits reference bursts which are used to provide timing information to all of the terminals 22. Each of the terminals 22 generates a "Start Of Transmit Frame" (SOTF) using this timing information. An interval of time on one carrier constitutes a unidirectional communication channel. A fixed length interval of time on a particular carrier is called a "burst" and is the basic unit in which bandwidth is allocated. Thus, a burst constitutes a unidirectional communication channel over a link between the sender terminal to the receiver terminal. Each

terminal 22 can transmit or receive on only one burst at a given time. These bursts are allocated and deallocated by the NCC 24.

Each of the terminals 22 is equipped with a transmitter/receiver 29 that includes a modem 30 that can send and receive TDMA bursts. A burst can be on various different carrier frequencies, can be of various lengths, and can start at various offsets from the SOTF, using either a BPSK or QPSK modulation technique. The modem 30 within each terminal 22 also includes an internal mechanism for monitoring various performance parameters of the modem 30 (e.g., Bit Error Rate (BER), Signal-to-Noise (S/N) ratio, etc.) and for generating modem performance information indicative of the current value of such modem performance parameters.

Each of the terminals 22 is also equipped with a programmable controller 39, and the NCC 24 is also equipped with a programmable controller 41. The programmable controller 39 in each of the terminals 22 and the programmable controller 41 in the NCC 24 are programmed to implement the methodology of the present invention described briefly hereinabove, and as will now be described in greater detail with additional reference to FIG. 2. In general, the controller 39 within each of the terminals 22 is programmed to provide the various functional entities that are depicted in FIG. 2, and the controller 41 within the NCC 24 is programmed to provide the various functional entities and data structures depicted in FIG. 2.

More particularly, the controller 39 in each terminal 22 is programmed to provide a functional entity designated as the Performance Reporter 45 and a functional entity designated as the Channel Access Control (CAC) or TDMA Driver 47. The controller 41 in the NCC 24 is programmed to provide a functional entity designated as the Performance Manager 49, a functional entity designated as the Capacity Manager 51, a data structure designated as the Modulation Translation Table 53, and a data structure designated as the Terminal Status Table 55.

The Performance Reporter 45 periodically queries the modem 30 in order to obtain the current modem performance information therefrom, and then sends reports regarding modem performance (i.e., modem performance reports) to the Performance Manager 49. The CAC 47 controls the TDMA hardware within the transmitter/receiver 29 to transmit or receive bursts in

accordance with burst allocation/deallocation control information sent by the Capacity Manager 51 to the CAC 47. The burst allocation/deallocation control information regarding the transmit bursts originating from and terminating at a particular terminal is sent by the Capacity Manager 51 in the NCC 24 to the CAC 47 at that terminal.

The Performance Manager 49 receives modem performance reports from all of the terminals 22 in the network 20. The Modulation Translation Table 53 contains a set of data entries that indicate the particular modulation type (BPSK or QPSK) to be used for respective sets of values of the modem performance parameters. The Terminal Status Table 55 contains data entries that indicate the currently selected modulation type for each of the terminals 22 in the network 20.

The Performance Manager 49 consults the Modulation Translation Table 53 to determine the type of modulation which should be used for a particular terminal 22 based upon the current performance of the modem 30 of that particular terminal 22 as reflected by the modem performance report received from the Performance Reporter 45 of that particular terminal 22. Thus, since the current performance of the modem 30 of that particular terminal 22 is directly affected by the prevailing link quality or conditions (e.g., clear sky or heavy rain), the type of modulation selected at any given time for that particular terminal 22 will be dependent upon the prevailing link quality or conditions at that given time.

The Performance Manager 49 then updates the modulation type data entry in the Terminal Status Table 55 for that particular terminal 22 with the preferred or selected modulation type for the prevailing link conditions. The Capacity Manager 51 allocates and deallocates bursts between various pairs of terminals 22 (i.e., over various links) by sending the burst allocation/deallocation control information to the CAC 47 of the respective terminals 22. When allocating bursts, the Capacity Manager 51 consults the Terminal Status Table 55 to determine the selected modulation type to be used during allocation of a burst. The burst allocation/deallocation control information includes a data segment that identifies the selected modulation type to be used for a given burst.

Preferably, if two terminals (i.e., the sending and receiving terminals for a given link)

have different selected modulation types, then the more conservative modulation type is selected by the Capacity Manager 51. For example, if BPSK is the selected modulation type for a first one of a pair of terminals for a given burst over a given link and QPSK is the selected modulation type for a second one of the pair of terminals for that given burst over that given link, then the Capacity Manager 51 uses BPSK as the modulation type when allocating that given burst. In essence, in the event of a mismatch between the selected modulation types for the sending and receiving terminals of a given link, the Capacity Manager 51 can be programmed to select a default modulation type, which is preferably the more conservative modulation type, i.e., the modulation type appropriate for adverse link conditions, as opposed to the modulation type appropriate for favorable link conditions.

As will be readily appreciated by those having ordinary skill in the pertinent art, the specifically contemplated implementation of the adaptive modulation subsystem of the present invention described above provides 3 dB of gain when the information throughput is decreased by 3 dB due to link degradation, while maintaining a constant symbol rate, thereby enabling acceptable bit error rate performance for the network despite variations in link conditions. The 3 dB gain is provided by changing the modulation type from QPSK to BPSK. Further, it will be readily appreciated that the mechanism for detecting changes in link conditions and for changing the modulation type in response to changing link conditions operates on a burst-by-burst basis, thereby ensuring rapid response to changes in link conditions. In particular, this implementation assures that the necessary transmit/receive configuration changes are effectuated as soon as possible in response to detected changes in link conditions.

It will be appreciated that the particular modem performance threshold (e.g., BER and/or S/N ratio) that is chosen for changing modulation type (at the Performance Manager) will vary depending upon the error tolerance for a given application. In particular, the level of error correction built into the data coding scheme employed for a given application (i.e., the robustness of the resultant bit stream) largely determines the level of error tolerance (i.e., the maximum tolerable BER) for that given application. However, a number of other significant factors, such as the cost and complexity of the signal processing circuitry (e.g., codecs) employed in the terminals, and the type of data being handled, can also influence the level of error tolerance for a given application. For example, the acceptable BER for a digital video stream will typically be

much higher than the acceptable BER for a mission-critical digital missile system control data stream, since some picture distortion is normally acceptable, whereas a misfiring of a missile is unacceptable.

The particular hardware implementation of the modulator and demodulator portions of the modem 30 of each terminal 22 is a routine matter for a person of ordinary skill in the pertinent art. For example, a universal ultra-precision PSK modulator disclosed in U.S. Patent Number 4,562,415, issued to McBiles, and the QPSK/BPSK demodulator disclosed in U.S. Patent Number 4,833,416 may be used. The disclosures of these two patents are incorporated herein by reference. However, the particular hardware implementation will depend upon the cost/performance parameters of a given application, and will typically be a matter of designer's choice.

With respect to the specific exemplary implementation of the present invention described hereinabove, the modulator can be easily designed to be capable of operating in both QPSK or BPSK modulation modes, particularly since the present invention does not require that the FEC code rate be varied or modified, regardless of variations in link conditions. In particular, the same bit stream is fed to both the In-phase (I) and Quadrature-phase (Q) arms of the modulator in both modes of operation. The modulator operation is identical in both modes of operation. The only requirement is that there be provided a mechanism for reducing the information throughput (i.e., the bit rate of the bit stream fed to the I and Q arms of the modulator) when switching from the QPSK to the BPSK modulation mode of operation.

With respect to the specific exemplary implementation of the present invention described hereinabove, at least two demodulator implementation options are possible. A first option is to use a demodulator that operates in identical fashion in both QPSK and BPSK modes, with the only difference being external to the demodulator, namely, the only difference being that, in the BPSK mode, the I and Q samples are added prior to the decoding operation. A second option is to use slightly different demodulator designs for the QPSK and BPSK modes. Specifically, standard QPSK synchronization can be used for the QPSK mode, and standard BPSK synchronization can be used for the BPSK mode.

The first option results in a simpler implementation than the second option, but results in a slight performance degradation when compared to the second option. However, the increased complexity of the second option can be minimized by making use of common elements for implementing the synchronization function for both modes. In many applications, the synchronization functions are implemented in firmware using field programmable gate arrays (FPGAs), and thus, the added complexity simply amounts to a few extra lines of code.

Although an exemplary and presently preferred embodiment of the present invention has been described in detail hereinabove, it should be clearly understood that many variations and/or modifications of the basic inventive concepts taught herein that may appear to those skilled in the pertinent art will still fall within the spirit and scope of the present invention as defined in the appended claims.

WHAT IS CLAIMED IS:

1. A method for compensating for changes of condition of an RF link, including the steps of:

periodically monitoring the condition of the RF link, and producing link condition information indicative of a current condition of the RF link; and,

adaptively varying a modulation type used over the RF link in response to a prescribed change in the condition of the RF link, based upon the link condition information.

2. The method as set forth in Claim 1, wherein:

the RF link includes a sender station and a receiver station that are each equipped with a modem; and,

the periodically monitoring step is carried out by monitoring performance of the modem of the receiver station.

3. The method as set forth in Claim 2, wherein the prescribed change in the condition of the RF link corresponds to a change in the performance of the modem of the receiver station above or below a prescribed modem performance threshold.

4. The method as set forth in Claim 3, wherein the link condition information comprises modem performance information indicative of a current value of at least one performance parameter of the modem of the receiver station.

5. The method as set forth in Claim 4, wherein the RF link is part of a satellite communication network that includes a plurality of terminals, including the sender and receiver stations, and a network control center.

6. The method as set forth in Claim 5, wherein the modulation type is selectable from a group that includes QPSK and BPSK, depending upon the current link condition.

7. The method as set forth in Claim 1, wherein the modulation type is selectable from a group that includes QPSK and BPSK, depending upon the current link condition.

8. The method as set forth in Claim 1, wherein the RF link employs a communication protocol in which the smallest unit of bandwidth allocation is a burst.

9. The method as set forth in Claim 8, wherein the periodically monitoring and adaptively varying steps are performed on a burst-by-burst basis.

10. The method as set forth in Claim 5, further including the steps of:

periodically sending the link condition information from the receiver station to the network control center;

at the network control center, periodically determining a preferred modulation type for the current link condition based upon the link condition information, and periodically sending modulation type control information indicative of the preferred modulation type to a modulation type control portion of both the sender and receiver stations,

wherein the adaptively varying step is carried out by the modulation type control portion of both the sender and receiver stations in response to the modulation type control information.

11. The method as set forth in Claim 10, wherein the periodically sending the link condition information step is carried out by a performance reporter functional entity in the receiver station that periodically sends modem performance reports to a performance manager functional entity in the network control center.

12. The method as set forth in Claim 11, further including the step of constructing a database at the network control center that includes a modulation translation table that contains data entries indicating a preferred modulation type for different possible link conditions, and a terminal status table that contains data entries indicating the preferred modulation type for each terminal in the network for the current link conditions.

13. The method as set forth in Claim 12, further including the step of the performance manager functional entity updating the terminal status table in response to the modem performance reports, using the modulation translation table.

14. The method as set forth in Claim 13, further including the step of a capacity manager functional entity in the network control center generating the modulation type control information based upon the data entries in the terminal status table for the sender and receiver stations.

15. The method as set forth in Claim 10, wherein the satellite communication network employs a communication protocol in which the smallest unit of bandwidth allocation is a burst.

16. The method as set forth in Claim 15, wherein the periodically monitoring and adaptively varying steps are performed on a burst-by-burst basis.

17. The method as set forth in Claim 14, wherein:

the satellite communication network employs a communication protocol in which the smallest unit of bandwidth allocation is a burst; and,

the capacity manager functional entity allocates bursts and generates the modulation type control information on a burst-by-burst basis when allocating bursts.

18. The method as set forth in Claim 1, further including the step of adaptively varying an information throughput of the RF link when adaptively varying the modulation type.

19. The method as set forth in Claim 16, further including the step of adaptively varying an information throughput of the RF link when adaptively varying the modulation type, while maintaining a constant symbol rate.

20. A satellite communication network that includes an adaptive modulation subsystem that implements the method set forth in Claim 1.

21. A satellite communication network that includes an adaptive modulation subsystem that implements the method set forth in Claim 19.

22. An adaptive modulation subsystem for compensating for changes of condition of an RF link, including the steps of:

means for periodically monitoring the condition of the RF link, and for producing link condition information indicative of a current condition of the RF link; and,

means for adaptively varying a modulation type used over the RF link in response to a prescribed change in the condition of the RF link, based upon the link condition information.

23. The adaptive modulation subsystem as set forth in Claim 22, wherein:

the RF link includes a sender station and a receiver station that are each equipped with a modem; and,

the periodically monitoring means monitors performance of the modem of the receiver station.

24. The adaptive modulation subsystem as set forth in Claim 23, wherein:

the prescribed change in the condition of the RF link corresponds to a change in the performance of the modem of the receiver station above or below a prescribed modem performance threshold; and,

the link condition information comprises modem performance information indicative of a current value of at least one performance parameter of the modem of the receiver station.

25. The adaptive modulation subsystem as set forth in Claim 22, wherein the modulation type is selectable from a group that includes QPSK and BPSK, depending upon the current link condition.

26. The adaptive modulation subsystem as set forth in Claim 24, wherein the modulation type is selectable from a group that includes QPSK and BPSK, depending upon the current link condition.

27. The adaptive modulation subsystem as set forth in Claim 22, wherein:

the RF link employs a communication protocol in which the smallest unit of bandwidth allocation is a burst; and,

the periodically monitoring and adaptively varying means operate on a burst-by-burst basis.

28. The adaptive modulation subsystem as set forth in Claim 27, wherein the RF link is part of a satellite communication network that includes a plurality of terminals, including the sender and receiver stations, and a network control center, and further comprising:

means for periodically sending the link condition information from the receiver station to the network control center;

means in the network control center for periodically determining a preferred modulation type for the current link condition based upon the link condition information, and for periodically sending modulation type control information indicative of the preferred modulation type to a modulation type control portion of both the sender and receiver stations,

wherein the adaptively varying means comprises a modulation type means in both the sender and receiver stations that are responsive to the modulation type control information.

29. A satellite communication network, comprising:

a plurality of terminals each of which is equipped with an RF transmitter/receiver that includes a modem and a programmable controller, and which produces modem performance information indicative of modem performance;

a network control center that includes a programmable network controller;

wherein the programmable controller of each terminal is programmed to periodically monitor the modem performance information and to produce link condition information that includes a current value of at least parameter of modem performance;

wherein the programmable network controller is programmed to periodically determine a preferred modulation type for each pair of the terminals that define a link, based upon the link condition information received from the terminals, and to periodically send modulation type control information indicative of the preferred modulation type to a modulation type control portion of both a sender and a receiver terminal of a link currently being controlled;

wherein the modulation type control portion of both the sender and receiver terminals adaptively varies a modulation type used by the modem in the terminal, in response to the modulation type control information.

30. The satellite communication network as set forth in Claim 29, wherein:

the satellite communication network employs a communication protocol in which the smallest unit of bandwidth allocation is a burst; and,

the programmable network controller includes a capacity manager functional entity that allocates bursts and generates the modulation type control information on a burst-by-burst basis when allocating bursts.

31. The satellite communication network as set forth in Claim 30, wherein the programmable controller in each terminal includes a performance reporter functional entity in the receiver station that periodically sends the link condition information in the form of modem performance reports.

32. The satellite communication network as set forth in Claim 31, wherein the programmable network controller includes a database that includes a modulation translation table that contains data entries indicating a preferred modulation type for different possible link conditions, and a terminal status table that contains data entries indicating the preferred modulation type for each terminal in the network for the current link conditions.

32. The satellite communication network as set forth in Claim 32, wherein the programmable network controller includes a performance manager functional entity that updates the terminal status table in response to the modem performance reports, using the modulation translation table.

33. The method as set forth in Claim 32, the capacity manager functional entity generates the modulation type control information based upon the data entries in the terminal status table for the sender and receiver terminals of the link currently being controlled.

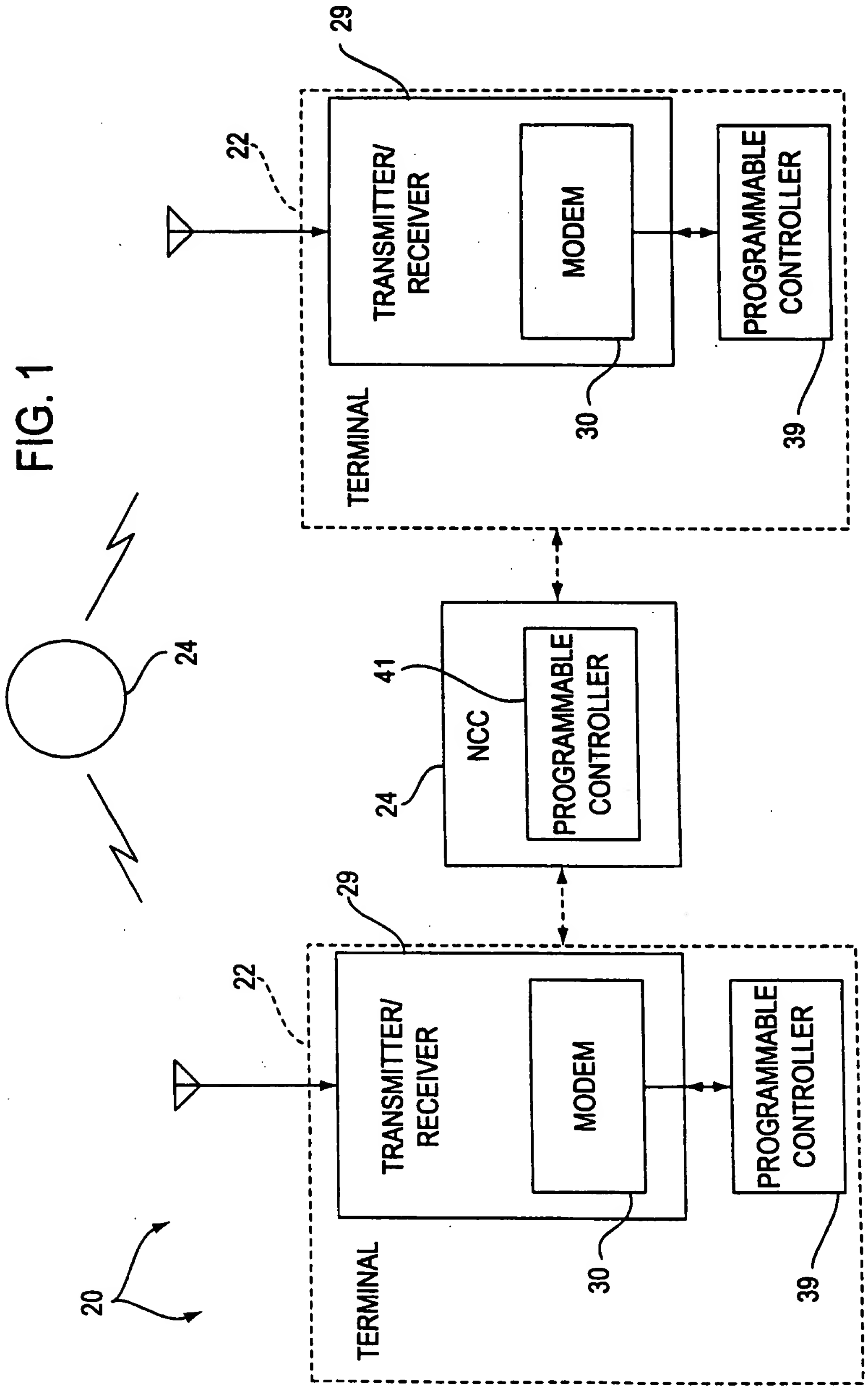
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FIG. 1

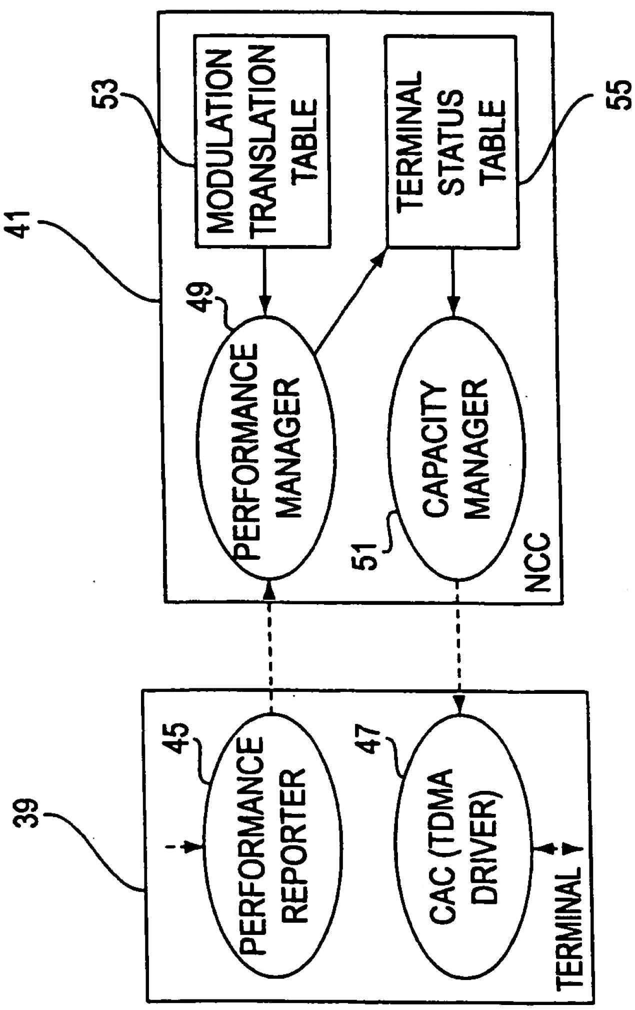
41
53
MODULATION TRANSLATION TABLE
TERMINAL STATUS TABLE
55
49
PERFORMANCE MANAGER
51
CAPACITY MANAGER
NCC
39
45
PERFORMANCE REPORTER
47
CAC (TDMA DRIVER)
TERMINAL

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/21634

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H 04 B 1/38; H 04 L 5/16
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/222, 224, 280, 281, 284, 285, 296, 340, 346, 377; 370/252, 333; 455/67.1, 67.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5,257,397 A (BARZEGAR et al.) 26 October 1993, figs. 1 and 4, see abstract, col. 2, lines 63-67, col. 3, line 6-col. 4, line 16.	1, 2, 22 and 23 3-9, 18, 20, and 24-27
X Y	US 5, 022, 024 A (PANETH et al.) 04 June 1991, see figs 2 and 21, abstract, col. 6, lines 56-67, col. 8, lines 54-60.	1, 2, 22, and 23 3-9, 18, 20 and 24-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 DECEMBER 1998	25 FEB 1999

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Jason Chan Joni Hill
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/21634

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

375/222, 224, 280, 281, 284, 285, 296, 340, 346, 377; 370/252, 333; 455/67.1, 67.3

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